The Newsletter of the Earth Sciences Directorate

Earth Sciences NEWS

NASA Goddard Space Flight Center Volume 4 Number1, Spring/Summer 1999

Message From the Director

Dr. Vincent Salomonson

As usual, the last few months have continued to be interesting. A highlight was the successful launch of Landsat 7. If you haven't seen some of the results, I suggest taking a look at the Landsat 7 Home Page. Along with Landsat 7 scientific results, other results continue to come in from the basic Research and Analysis (R&A) efforts and existing missions such as SeaWiFS, TOMS, UARS, and TRMM. It's just great to be in a position where one can at least get a glimpse of the great work that is being accomplished throughout the Directorate.

One prominent activity that took place in the last few weeks was the preparation for, and interaction with, the Earth Sciences Directorate Visiting Committee that came to review the Directorate on May 26 and 27. The Chairman of the Committee was Prof. Eric Barron (Penn State Univ.). Other members included Dr. David Cooper (Lawrence Livermore National Laboratories); Prof. Robert E. Dickinson (University of Arizona); Prof. Arnold Gordon (Lamont Doherty Earth Observatory); Dr. R. Michael Hardesty (Wave Propagation Lab, NOAA/ERL/Boulder); Prof. D. L. Hartmann (Department of Atmospheric Sciences, Univ. of Washington); Dr. Robert J. Serafin (National Center for Atmospheric Research); Prof. Soroosh Sorooshian (University of Arizona); Prof. Calvin T. Swift (University of Massachusetts/Amherst); and Professor Byron Tapley (University of Texas/Austin). This was a very strong committee, and we appreciated the time and effort they put into the review of Directorate activities.

The Directorate senior staff provided overviews of activities to the Visiting Committee on the first day of the review. They visited with individuals or examined facilities on the second day before preparing preliminary findings and the outline of their report. Essentially, we indicated to the Committee that our principal strengths are: 1) The breadth of scientific expertise in Earth sciences that exists within the Directorate; 2) our comprehensive capability for modeling the Earth-atmosphere system, components of the system, and the various processes operative in the Earth-atmosphere system; 3) the power and comprehensiveness of the GSFC/Directorate computing and data storage systems; and 4) the major strengths that exist in multispectral/hyperspectral, lidar, and microwave remote sensing and attendant data analysis and interpretation. Based on these strengths, some future Directorate-wide research and development thrusts were presented. They included: 1) Studies and missions related to changes in the climate system on seasonal-to-interannual scales, including coupled land/ocean/atmosphere

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Observing Locally, Understanding Globally: Landsat 7

Dr. Mitchell K. Hobish

An urban planner. A scientist. A farmer. A land developer. A student.

What do these people have in common?

They'll all directly—and inexpensively—benefit from data to be obtained by the latest in the Landsat series of satellites.

Landsat 7, launched on April 15, 1999, will provide repetitive, broad-area coverage to continue a more than a quarter-century of observations of seasonal changes on regional, continental, and global scales.

The Landsat series of satellites came into being as a result of the humans-in-space program. There was early and obvious excitement about the views of the Earth provided by photographs taken by Mercury, Gemini, and Apollo astronauts. The United States Geological Survey even had plans to put its own satellite in orbit to acquire remote-sensing data of the Earth. NASA, however, had the wherewithal to make this happen expeditiously, and developed the Earth

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Resources Technology Satellite (ERTS), which was launched on July 23, 1972. The follow-ons to ERTS were later renamed Landsat. They used a multispectral scanner, Landsat 4, launched in July 1982, provided the first use of a workhorse instrument, the Thematic Mapper (TM), which was also used on Landsats 5 and 6. Landsat 6, under commercial management, unfortunately never made it into orbit. While Landsat 5 had a design lifetime of three years, it has been functioning well for over 15 years. This longevity has provided the time needed to develop a new instrument, the Enhanced Thematic Mapper Plus (ETM+), being flown for the first time on Landsat 7.

Landsat 7 will do more than continue this unbroken stream of data. Early Landsats had on-board reel-to-reel recorders that were not robust, and therefore wore out. Landsats 4 and 5 had no recorders, but were designed to utilize the Tracking and Data Relay Satellite System (TDRSS). The transmission transistors on Landsat 5 failed in the early '90s, so while data acquisition has continued, there has been no global coverage for most of this decade. Landsat 7 has an on-board, solid-state recorder, which will allow acquisition—and subsequent transmission—of some 100 scenes daily. This daily data rate will exceed that expected from Terra, another EOS-era satellite to be launched later this year. In addition to the storage capability, Landsat 7 is capable of direct transmission to ground stations.

Another key difference in the Landsat 7 project is how the data will be distributed. The Landsat program was commercialized under the Reagan administration, with Space Imaging (EOSAT) handling all data requests and distribution. Their pricing schemes—some $4,500 per scene—placed the available data well out of the reach of all but the most well-heeled researchers. Further, the company was not involved in research per se, and so scenes would be imaged upon request, but not necessarily on a global basis. There were significant copyright restrictions on the purchased scenes, further limiting their distribution.

Landsat 7 will change that. The data to be provided by the satellite will be made available at the Cost for Fulfilling User Requests (COFUR). The law now stipulates that, in coming up with the COFUR, the cost of building or launching the satellite, or the facility to acquire and process the data, cannot be written off or amortized. Users will be charged the marginal cost of retrieving the data from the archive, creating the product, and shipping it to the user. This reduces to about $475 per uncorrected (Level 0R) scene. After radiometric and geometric corrections have been made (Level 1R1G product), the price will be $600. There are no copyright restrictions on purchased scenes, so Dr. Darrel Williams, the Landsat Project Scientist, expects a tremendous burst in access to Landsat 7 scenes. Where research teams who couldn't afford EOSAT-based imagery were relegated to analyzing data from the pre-commercialization 1980's data, Williams says, "With the ability to process [the data] with a Pentium PC, we really expect use to explode, starting even in middle school and high school and on up." Browse imagery—useful for determining image location, quality, and information content—will be available over the Internet without cost within 24 hours of receipt of the data at the EROS Data Center.

This is where Landsat 7 diverges most clearly from its progenitors. With the reduction in per-scene fees, removal of copyright restrictions, and the increase in computing power available to "average" users, Landsat 7 data should be usable (and used) by a wide swath of the potential user community.

The nature of the data is also relevant to this community-use growth. Building on the heritage of the TM, the ETM+ on Landsat 7 will provide high-resolution imaging of the Earth's surface at visible, near-infrared, shortwave, and thermal-infrared wavelengths in a 183-kilometer-wide swath. Spatial resolution will be on the order of 15 m in the panchromatic band, 30 m in the visible, near- and shortwave IR bands, and 60 m in the thermal IR band. When coupled with absolute radiometric calibration, these capabilities are unmatched in current or planned remote-sensing systems.

The data will extend and improve upon the historical record of global land cover, and enable improved regional-to-global land-cover assessment and carbon-budget analysis. Specifically, they will be useful to document rates and processes of land-cover change around the globe, such as deforestation and fragmentation of ecosystems, measurements of urban growth and population migration, agricultural-productivity assessment and prediction, and fire-damage assessment.

In the area of the carbon cycle, Landsat 7 data can be used to assess biomass loss due to clearing and logging, ecosystem degradation, forest regrowth patterns, and the role of fire. The data also can be used to support land-management practices, and monitor year-to-year changes in growth and disturbance.

In the area of long-term climate variability, extending the 26-plus years of existing Landsat coverage will help identify terrestrial response to climate change, and yield more accurate predictions of the effects on social and natural systems. These areas include alpine snow and ice cover, glacier dynamics, lake-level dynamics, vegetation succession and seasonality, and landform evolution.

On shorter time scales, Landsat 7 data will lead to improved estimates of terrestrial biophysical and biochemical

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A Novel Way To Use Landsat Data

Renny Greenstone

Anyone who gives even a little thought to the Landsat program and its particular name would be forgiven for assuming that its purpose is to provide us with information about the *land* surface of the Earth. In fact, when the Landsat program was first undertaken, it was given the name ERTS, for Earth Resources Technology Satellite. Through the years, the scientists who have been using the Landsat data have typically rejected any of the Landsat scenes that were felt to be "contaminated" by clouds. Thus, it comes as a bit of a surprise to find that Dr. Robert Cahalan (Code 913) and co-workers are analyzing data from the very scenes that were considered to be of little or no use by the community of land-surface investigators. Cahalan (Principal Investigator) and his coworkers have been studying cloud information provided by the various satellites in the Landsat series since 1982. Working with Dr. Cahalan are Co-Investigators Harshvardhan of Purdue University (formerly at Goddard), S.-C. Tsay and W. J. Wiscombe (both at Goddard), and Associate Scientists Lazaros Oraiopoulos and Guoyong Wen (both at UMBC/JCET).

As Dr. Cahalan says, "The research is aimed at forging a link between Landsat and the number-one unsolved problem in global climate modeling, the role of clouds in contributing to Earth's climate." Dr. Cahalan's project has four complementary thrusts, not only to attack the problem of clouds and climate, but also to assist land-surface researchers by giving them improved "corrections" for the interference effects of clouds.

The **primary thrust is** "cloud-scaling analysis," and, in particular: 1) Sophisticated analysis of Landsat imagery to reveal the essence of cloud "macrostructure," to reveal the range of variability of characteristic cloud parameters and their dependence on cloud type and location; 2) development of fractal- and wavelet-based models of spatial distribution of water substance in clouds; and 3) application of Monte Carlo (random calculations) radiative-transfer methods to the modeled clouds in order to be able to estimate solar-energy flux for climate purposes and also to improve calculations of cloud properties from the MODIS instrument that will be flying on the EOS satellite missions.

The **second thrust** of the project is to provide new and better clear-sky atmospheric corrections for Landsat to improve on techniques for discriminating clear sky from cloudy conditions. This has led to development of a "path-radiance" correction method that has the potential to detect lower aerosol amounts, and to be applied to a broader range of surfaces than previous methods.

The **third thrust** of the project is to link the Landsat program with the Department of Energy's main global-change research program, called ARM (the Atmospheric Radiation Measurements Program), so that ARM data can be used to validate Landsat clear-sky atmospheric correction and retrieval of cloud properties, especially during so-called "intensive operational periods" at each of the three ARM sites—the "North Slope Alaska" site near Point Barrow, Alaska, the "Southern Great Plains" site near Lamont, Oklahoma, and the "Tropical Western Pacific" site at Manus Island in the equatorial Pacific Ocean.

The **fourth and final thrust** of the project is to provide methods for improving the modeling of cloud structure and cloud radiation in Global Climate Models (GCMs), by incorporating "effective" cloud properties into cloud parameterizations used by the models. Dr. Cahalan has collaborated on this with Drs. Tietdke and Morcrette and their colleagues at the European Centre for Medium-Range Weather Forecasting (ECMWF) in Reading, England, and has reported results from global runs of a 25-km-resolution version of the ECMWF's forecast model (TL639) at the spring 1999 AGU meeting, in Boston.

Since fractals are so important in Dr. Cahalan's work, and, as he says, they improve the understanding of cloud properties, we should spend a little time understanding the importance of knowing cloud properties. Here are some thoughts on clouds and fractals:

Clouds play a critical role in the Earth's hydrologic cycle and in the energy balance of the climate system. They have a strong effect on solar heating by reflecting part of the incident solar radiation back to space. An increase in the average albedo of the Earth-atmosphere system by only 10 percent could decrease the Earth's surface temperature to that of the last ice age. Clouds affect the thermal cooling by intercepting part of the infrared radiation emitted by the Earth and atmosphere below the clouds, and re-emitting part of this radiation back to the surface, while sending the remainder out to space. Global change in surface temperature is highly sensitive to cloud amount and type. Increasing low-level and middle-level clouds has a net cooling effect because these clouds reflect more solar radiation and have a relatively small effect on infrared radiation. On the other hand, increased high clouds will have a warming effect by virtue of their low temperature and reduced cooling to space. High cirrus clouds also act as natural cloud seeders and strongly modulate the radiatively important upper tropospheric water

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vapor budget. Given the sensitivity of the global climate to clouds, it is not surprising that the largest uncertainty in model estimates of global warming is due to clouds.

Climate models and remote sensing typically have depended on over-simplified homogeneous "plane-parallel" models. These employ "effective" cloud parameters, such as cloud liquid-water content, which depend on the macrophysical and microphysical properties of clouds. Dr. Cahalan points out that by using inhomogeneous fractal cloud models he can determine the dependence of these effective cloud parameters on macrostructural parameters such as the variance and wavenumber spectra of cloud liquid water. Fractal cascades designed for various cloud types generate cloud layers having a range of inhomogeneities, and Monte Carlo methods then determine the radiative properties of such clouds. Fractal clouds are generally less reflective than plane-parallel cloud, which have the same total cloud liquid water, and, equivalently, fractal clouds contain more liquid water than plane-parallel clouds which have the same reflectivity. The fractal clouds then provide the connection between local measurements made in real clouds and idealized plane-parallel clouds employed by large-scale models.

Dr. Cahalan and his colleagues are now organizing an "Intercomparison of 3D Radiation Codes" (I3RC), that will apply Monte Carlo and other methods of 3-dimensional transfer to a variety of inhomogeneous cloud fields derived from Landsat and ARM data, as well as cloud models, to compare the accuracy and timing of the various methods, and to study the reflection and absorption of both solar and thermal radiation by clouds. The first I3RC workshop, in Tucson, November 17-19, 1999, will involve groups participating from around the world.

If you want to know more about clouds and their effects on climate, check the NASA fact sheet on Clouds and the Energy Cycle, and also Dr. Cahalan's Web site at http://climate.gsfc.nasa.gov/~cahalan.

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Observing Locally, Understanding Globally: Landsat 7

linkages to the climate system, thereby addressing interannual climate dynamics. This includes local vegetation patterns, local sources of environmental variability, estimation of ecosystem productivity, and coral-reef dynamics.

Prediction and possible mitigation of natural hazards requires the global, high-resolution coverage afforded by Landsat 7. Examples of natural-hazard investigation include monitoring active volcanoes, determining the local impact of droughts and floods and, the impact of storms on coastal areas, flood-hazard mapping, landslide monitoring, and determining the impacts of forest fires.

All these data are complementary to, and integrate with, other existing and planned data sets. Indeed, orbital parameters for Landsat 7 will take advantage of the similar orbit of the Terra platform, and investigators will use ETM+ data to augment data from Terra instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS). The orbits are same-day 705-km orbits, approximately 30 minutes apart. Landsat ETM+ data will provide input to Terra data analysis in the areas of vegetation classification for MODIS and Multiangle Imaging Spectro-radiometer (MISR) biophysical products. The data will also focus on global-change hotspots detected by MODIS and MISR. They will also link Terra observations with the 26+ year Landsat archive, and provide radiometric rectification of MODIS data. Terra will provide input to Landsat 7 data via use of MODIS and MISR for improved atmospheric correction and temporal interpolation for the ETM+ and for cross-calibration.

One of the major benefits of all this, according to Williams, is that students and the lay community will have ready access to all these data. For students, "…we just want them to become comfortable and familiar with looking at the environment around their own school. If they get comfortable with this, then they can go elsewhere for more information." Unlike Project GLOBE, where students provide direct input to scientific investigations, there's no formal feedback mechanism in place for Landsat 7.

"We encourage the students to create posters or write papers, but we're not looking for direct feedback," says Williams. "The sooner that students can become comfortable with looking at the Earth in this new way, the better off we'll all be in the long run."

For additional information on Landsat 7 and the Landsat program generally, see *http://landsat.gsfc.nasa.gov/* and links contained therein.

Water, Water Everywhere

Dr. Mitchell K. Hobish

"Water, water everywhere, nor any drop to drink . . ."

The Rime of the Ancient Mariner
Samuel Taylor Coleridge

Fortunately, we're not in the dire straits of Coleridge's ancient mariner, but the quotation above does point up the importance of water for living things.

Given this importance it should come as no surprise that a major component of Earth system science research deals with the hydrosphere: the state, distribution, and dynamics of water in the Earth's systems. It is to this end that GSFC's Code 970—the Laboratory for Hydrospheric Processes—has been organized. Unlike most other organizations at GSFC, Code 970 is made up of a flight project, two branches performing basic research, and two branches performing applied research and technology development.

At the moment, the "apple" of Lab chief Dr. Tony Busalacchi's eye is the flight project, the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS; Code 970.2), the data from which, he says, are ". . . revolutionizing biological oceanography and . . . starting new fields in ocean science."

SeaWiFS is a conceptual follow-on to the Coastal Zone Color Scanner (CZCS), flown on the venerable Nimbus-7 satellite, launched in 1978. CZCS was a proof-of-concept mission, with a limited duty cycle. CZCS generated composites of ocean color, chlorophyll concentration, and primary production, but nothing that could be used to give a precise estimate of the seasonal/interannual variability. But where CZCS was somewhat limited (albeit very successful), SeaWiFS is a full-up, operational mission designed to acquire global observations every two days.

The kinds and amounts of data being acquired by SeaWiFS amply point up one of the other reasons that Code 970 is unique: Hydrospheric processes pervade much of what goes on in the Earth's various systems and form interfaces between them. It is this "working at the margins," according to Busalacchi, that makes Code 970 such a great place to be working. Says Busalacchi, "SeaWiFS is at the interface between the physical climate and biogeochemical cycles." With increasing evidence of coupled climate modes across the major ocean basins, acquiring, analyzing, and understanding the data from missions like SeaWiFS enhances the possibility for predictive capability of not just the coupled climate system but the interaction with the biosphere as well.

Another example of the breadth in this scientific organization is a technology group, the Microwave Sensors Branch (Code 975). Because of the utility of microwaves in detecting and measuring hydrospheric proc-esses, having a technology branch within a nominally scientific organization is another natural fit.

There are several healthy collaborations between the Laboratory for Atmospheres (Code 910) and Code 970 generally, and the Microwave Sensors Branch forms a kind of bridge. For example, Code 975 has performed much of the algorithm development for the active microwave rainfall retrievals for the Tropical Rainfall Measuring Mission (TRMM). While the scientific justification to develop aircraft instruments for actively and passively profiling the atmosphere column comes from Code 910, the instrument development and engineering often derives from Code 975 for meteorology. In addition, Code 975 develops technology for other parts of Code 970, such as realizing the potential for remote sensing of soil moisture and sea-surface salinity via passive-microwave approaches.

Another technical branch, the Observational Science Branch (Code 972), is located at Wallops Island, VA. Busalacchi's eyes light up when he discusses the Wallops facility. "Wallops is an exciting place," he says. "While we hear all about TOPEX/Poseidon observations, a lot of people don't realize that the place where radar altimeter observations were first done was at Wallops. It really is a kind of seat-of-the-pants sort of operation, and it allows us to be doing a lot of innovative things like using laser altimetry to map the Greenland ice sheets." The facilities at Wallops amply support other Code 970 and NASA activities, and include aircraft and a 20-m wave tank, which allow investigators to explore wave-current interactions and how the surface properties of the ocean interact with electromagnetic radiation for remote sensing. The geographic distance between GSFC and Wallops leads to some logistical difficulties, but telecommunications and shuttles to move people between the two facilities help mitigate the problems. Difficulties notwithstanding, it is the crew at Wallops who fly out over the oceans to monitor coastal erosion and provide the rest of us with data to determine the real-world, practical effects of storms and other events resulting from phenomena like last year's El Niño and Nor'easters hitting the Atlantic seaboard.

As a complement to the applied research and technology of the laboratory, the two "purely" scientific branches in Code 970 are the Oceans and Ice Branch (Code 971), and the Hydrological Sciences Branch (Code 974), both of which form the core

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around which the rest of the Laboratory orbits.

The Oceans and Ice Branch performs research to exploit and explain variability in remotely sensed data, from space-based platforms, of the ocean and cryosphere. The Branch concentrates on four main areas of research: physical oceanography, air-sea interaction, ocean color, and cryospheric processes. Models and data are used to study ocean circulation in the context of Earth systems dynamics. Of particular interest at low latitudes—since the oceans and atmosphere are strongly coupled and their interaction moderates climate change—are interannual phenomena such as El Niño. Models working at various spatial and temporal scales address various forcings of ocean circulation. Large-scale ocean circulation is investigated by analyzing satellite data and by using data-assimilation techniques. At high latitudes, one of the longest Earth observation records from space is the more than 20 years of passive microwave measurements of sea-ice concentration and extent that the cryospheric scientists in the Branch have processed and analyzed. Throughout, data and models are also used to provide input to develop new instruments and satellite projects to provide better measurements of critical ocean and climate phenomena. A key example of this is the future possibility of remotely sensed sea surface salinity from space.

The Hydrological Sciences Branch (Code 974) is a unique organization within NASA dedicated exclusively to understanding the different components of the hydrological cycle, with particular emphasis on land-surface hydrological processes and their interaction with the atmosphere. Remotely sensed data—with their integrative spatial and temporal properties—and land-surface hydrological, meteorological, and climatological modeling are employed in this effort. To realize this potential, the Branch is developing, testing, and applying algorithms for translating remotely sensed measurements into soil-moisture content, snow mass, precipitation, evapotranspiration, vegetation density, and other relevant hydrological quantities at the land/atmosphere interface. In addition, hydrological and atmospheric models are being developed concurrently that utilize remote-sensing data for input, calibration, validation, and assimilation within a wide range of temporal and spatial contexts. All of these studies serve to improve our understanding of how the various components of the hydrological cycle interact, and provide us with important information about the current structure of global hydrology and how mankind is changing the hydrological environment.

Because so much of the work done in Code 970 deals with interfaces, margins, and interactions, it is natural that people migrate to new ways of looking at the Earth and its systems. Out of such a migration grew the NASA Seasonal-to-Interannual Prediction Project (NSIPP). NSIPP will combine data assimilation with global and regional climate models for better understanding and experimental prediction of El Niño and similar-scale seasonal-to-interannual climate phenomena. Busalacchi is particularly proud of the people across Code 900 associated with this project, as they saw that the need for such an effort "...was almost self-evident, to the point where people made individual, personal scientific sacrifices, giving up their own personal scientific interests for the greater good, so that the sum of the parts was greater than the individual." He also says that NSIPP is, "...one of the best examples of taking advantage of the breadth across disciplines that the Goddard Earth Sciences Directorate possesses. I would submit that nobody in the world—nobody in the world!—has the breadth of Earth sciences across the disciplines that Code 900 has. Not NCAR, not the European Center, not Max Planck, not BMRC in Australia, not JMA in Japan, nobody has the breadth across the Earth sciences."

Busalacchi himself is a prime example of the skills and talents being brought to bear on this important topic. He recently won the prestigious Presidential Rank Meritorious Executive Award for his career accomplishments at NASA in studies of El Niño, ocean remote sensing, and coupled climate modeling. Moreover, recently he was selected as chairman of the International Scientific Steering Group for the World Climate Research Programme on Climate Variability and Predictability (CLIVAR).

It is the stunning breadth of talent across many disparate disciplines and interests that makes the Earth Science Directorate such a vibrant, exciting place, and Code 970 a perfect example of how those talents can be brought to bear upon a tremendous area of study: the Earth and its liquid assets.

[For additional information, see the Laboratory for Hydrospheric Processes' home page at http://neptune.gsfc.nasa.gov/970_home_ page.html]

Bonding Between Discovery Channel Online and NASA

Watch for the ever-tighter links now forming between NASA and Discovery Channel Online. In a really exciting move, Discovery Online, in cooperation with NASA's Earth Science Enterprise and Goddard, has selected its *first* Earth Science reporting fellow. This collaboration has just come into being, while, for some time now, Goddard scientists have been supplying images to Discovery's Planet Cam from SeaWiFS (see page 8) and TOMS.

Shahid Habib:
The New Player In the Earth Sciences Directorate

Renny Greenstone

Since January of this year, there's been a new player on the first floor of Wing E of Building 33. Dr. Shahid Habib bears the formidable title of Assistant Director of Technology and Projects for the Earth Sciences Directorate. He reports directly to the Directorate Chief, Dr. Vince Salomonson. The way he sees it, Dr. Habib brings his particular strengths as a systems manager to our Directorate.

Simply put, Habib is responsible for the strategic planning of the Directorate insofar as new instruments and technologies are to be brought to bear on the remote-sensing activities of the Directorate. In the world of ever-limiting budgets, it is more and more important to seek out technology developments by other divisions of NASA, not just the Earth Science Enterprise, other U.S. agencies, and other countries of the world. Tight budgets do not permit NASA the luxury of going it alone as was typical in the early days of the Earth Observing System (EOS).

In terms of strategic planning, Dr. Habib has to look toward the future of the role to be played in the Earth Sciences by the Directorate. New thrusts are being identified by the Headquarters Office of Earth Science (OES), and new missions are being called for. How will the Directorate participate in carrying out the new missions? Where does the Directorate fit in?

It is clear from developments that we have all seen in EOS that NASA has a new way of doing things. Missions that are now being planned are much more concerned than in the past with being innovative and reducing costs. Development cycles are being shortened. Spacecraft are smaller and lighter, allowing the use of smaller launch vehicles with consequent cost savings.

Dr. Habib tracks developments within NASA, taking into account developments in the Earth System Science Pathfinder (ESSP) program, the New Millennium Program (NMP), and the Instrument "Incubator" Program (IIP). ESSP offers the opportunity to have quick, low-cost missions that address areas of science that were not foreseen when the EOS program was devised about 10 years ago. Despite being quick and low cost, they might still incorporate new technologies or novel applications of existing technologies. NMP is charged to develop and flight validate "breakthrough" technologies to reduce the cost of high-priority science missions, while at the same time enhancing their scientific capability. The focus of IIP is to demonstrate new measurement technologies through "ground-based laboratory" activities.

There are other instrument development activities in NASA beyond those sponsored by the Office of Earth Science. Dr. Habib points particularly to the Cross Enterprise Technology Development Program as another source of technology research and developments that may be applicable to the activities of the Earth Sciences Directorate. In all of these NASA areas, Habib is particularly concerned with how our Directorate will be able to take advantage of the achievements of these groups. It isn't just Earth-oriented instrument research that will contribute to new or better instrumentation he points out. Historically, some of the most advanced remote-sensing instrumentation has been developed by the astronomers who perform space research, and Habib will continue to monitor developments that might be thought to belong the Space Science Enterprise at NASA Headquarters, but might also be of great benefit to Earth Science.

Dr. Habib will be looking for opportunities to partner with other U.S. agencies such as the Naval Research Laboratory, the Department of Defense, and the Department of Energy. These organizations can also provide significant contributions to NASA's program of Earth Science. And, of course, there are many opportunities, many ongoing at this time, to partner with the Earth science programs of the many countries around the world that are now increasingly involved in remote sensing of the Earth.

Habib has now spent about 10 years with NASA. At NASA Headquarters, he was the Program Manager for the Chemistry Mission in the Flight Systems Division. Before that he was in industry serving as manager of Martin Marietta's program to develop a new air traffic control system for the FAA. Since coming to Goddard he has had the fascinating role of coordinating with Russia and Ukraine to enssure the success of the cooperative mission to launch NASA's SAGE III instrument on the Russian Meteor 3M-1 spacecraft.

Dr. Habib and his wife Nasreen, live in Fairfax and have three daughters, ranging in age from 9 to 18. The eldest is studying in a joint program of engineering and medicine at the Virginia Commonwealth University-Medical College of Virginia. All of Dr. Habib's degrees are in electrical engineering. His D. Sc. degree, specializing in nonlinear systems and neural networks, came from George Washington University.

Science/Technology (and fun) at the North Pole

Renny Greenstone

On a recent trip to the Arctic, April 19-May 2, 1999, a group of Goddard personnel chose the North Pole as the unique site from which to demonstrate how new communications technologies and the Internet now make it possible for scientists working in very remote locations to send and receive data using NASA communications satellites. The group traveled to Resolute Bay and Eureka, Canada, before heading north to the "top of the world" to broadcast the first-ever live webcast from the North Pole. The two main objectives of this expedition were 1) to demonstrate the new communications technologies that made the live webcasts possible (the engineering); and 2) to take measurements of various aspects of the Arctic environment (the science). Of course, in carrying out these objectives, it was inevitable that there would be some fun and adventure for the participants as well. Part of the fun came from the ability to have live exchanges with students manning their own computers around the world to watch live video demonstrations by the expedition team, and to have Internet dialog with them.

The expedition demonstrated three new communications instruments (all developed at Goddard) that scientists will be able to use in the future while conducting field experiments. All three instruments used NASA's TDRS-1 system to complete the communications links: The TILT system transmits a high-quality signal appropriate for television or World Wide Web broadcasts at a relatively high rate; the ECOMM system also transmits a television and Web broadcast-quality signal, but at a much slower rate, however, at a fraction of the weight of TILT and consuming only one-third the power; and the PORTCOMM system yields an added communications capability while on the move. While moving in a car, a helicopter, and even a dogsled (fun/adventure?), the team was able to send data files although at an even slower rate than with ECOMM.

In addition to the communications element, there were scientific observations and measurements. The team collected ozone measurements with a hand-held Microtops Photometer, made Global Positioning System (GPS) measurements with a Trimble GPS Unit, and sea-ice-thickness measurements that they drilled with both powered and manual ice augers. The ozone measurements will be compared with satellite observations made by NASA's Total Ozone Mapping Spectrometer (TOMS), as checks on both the Microtops and the satellite data. GPS measurements from Resolute Bay will be used, in conjunction with later measurements, to examine glacial rebound (the uplifting of the land surface in response to the removal of the weight of the Pleistocene ice sheet. GPS measurements from the North Pole will be compared with corresponding measurements taken concurrently at the South Pole and in equatorial locations, to allow students to quantify easily the polar flattening of the Earth. The sea-ice-thickness measurements are being compared with other Arctic ice-thickness measurements made from the surface and from submarines.

Discover On-Line Hosts NASA Earth Sciences Images

Gene Feldman, Norman Kuring, and others on the SeaWiFS Project (Code 902) are getting NASA's message out to the public by way of the Internet. They tell us that the SeaWiFS Project is providing Discovery Online with true-color imagery of our entire planet twice a day for use in its Planet Cam webpage (http://www.discovery.com/cams/planet/planet.html). Clicking on any part of a small world map composed of the most recently collected day's worth of SeaWiFS data will display that part of the world at roughly 4-kilometer resolution. (Later, imagery from TOMS will also be made available.)

The software used to implement Discovery's Planet Cam pages was provided by the SeaWiFS Project, which had already developed a similar presentation of the data.

In addition to the Planet Cam, Discovery plans to host a "Best of" series on their Web site featuring recently collected 1-kilometer SeaWiFS images along with brief descriptions of the features depicted in the imagery. Pages like these may be used in conjunction with some of their news-related Web sites, such as the "Earth Alert" pages (http://www.discovery.com/news/earthalert/earthalert.html).

Norden Huang Receives an "Exceptional Space Act" Award

Cynthia M. O'Carroll and Renny Greenstone

Remarkable discoveries made by NASA scientists and engineers often have surprising applications in fields that seem remote from the work that led to them. A splendid example of this sort of serendipity can be found in the work of Dr. Norden Huang of the Laboratory for Hydrospheric Processes (Code 970) here at Goddard. Dr. Huang has been working at Goddard since 1975, much of the time studying the interactions of ocean surface waves and winds and currents. Information about winds over the oceans, and the currents and waves they produce, feeds into making better global weather and climate forecasts and improving understanding of climate cycles. It must have been as much of a surprise to him as to others working in the atmospheric and oceanographic fields to find that a discovery in those fields of Earth science would lead to breakthroughs in such far-removed fields as medical research and even submarine design!

In March of this year, Dr. Huang was the proud recipient of a NASA Space Act Award in the "Exceptional" category for his invention of a unique spectral-analysis method for analyzing nonlinear and nonstationary data and images. The award was presented in March at Goddard, and included a cash prize of $30,000.

Dr. Huang's new method of mathematical analysis may be a bit too esoteric for most of us to understand in any detail, but we can understand from the words of the NASA Headquarters Inventions and Contributions Board that this new method of data analysis has turned out to be "one of the most important discoveries in the field of applied mathematics in NASA history." This new method is expected to provide a more accurate result for analyzing nonlinear and nonstationary data than the classical Fourier method of spectral analysis.

Huang uses a formula in his method that was developed by the distinguished mathematician, David Hilbert. Therefore, the method is designated the Hilbert-Huang Transformation Method.

"I discovered the Hilbert-Huang Transformation Method by chance, while performing research using conventional methods, which are based on linear stationary assumptions," is the way Huang put it. "The world is not stationary, and many phenomena studied by scientists are the result of nonlinear processes."

Huang continues to be amazed by the "simplicity and diversity" of his new Hilbert-Huang Transformation Method. He points out that the method can be applied in a variety of fields well beyond Earth science to study things such as basic nonlinear mechanics, solar neutrino variations, earthquake engineering, geophysical exploration, submarine design, structural damage detection, satellite data analysis, nonlinear wave evolution, turbulence flow, blood-pressure variations, and heart arrhythmia.

NASA has filed four patents (as of the end of April) on the Hilbert-Huang Transformation Method (the first patent has been 'allowed'), and numerous research organizations have been granted access to the method through the NASA Space Act.

For example, Harvard Medical School is using the method to study changes in heartbeat as they relate to sleep apnea and epileptic seizures. The University of California at San Diego is using the new method to find a more accurate measure of "normal" blood pressure. This same method can also be used to study vibrations related to the health and safety of structures, such as buildings and bridges.

Dr. Huang received his undergraduate degree in 1960 from National Taiwan University. He received his doctoral degree in 1967 from Johns Hopkins University in Baltimore, where his field of study was determined by fate. The ship bringing him to the United States from Taiwan developed engine problems shortly after leaving the harbor. As a result, he arrived at the university late, after all the research positions related to structural or solid mechanics were taken. The only slot left was a research assistant in the Gravito-Hydrodynamics Laboratory. So he switched to fluid mechanics and eventually studied ocean waves for his doctoral dissertation. Dr. Huang was a postdoctoral fellow in the Oceanography Department of the University of Washington from 1967 to 1969. At North Carolina State University, he served both as an assistant professor and a tenured associate professor in oceanography from 1969 to 1975.

Through the years, he has published about 90 refereed papers. His paper on the Hilbert-Huang Transformation Method was published in the *Proceedings of the Royal Society of London* in 1998.

Among his awards are a NASA Medal for Meritorious Service in 1985 and a Best Publication Award in 1997. He served as an associate editor for the *Journal of Geophysical Research* (1984 to 1988), and since 1990, has been an associate editor for the *Journal of Physical Oceanography*.

Huang was born in Hubei, China, on December 13, 1937. He currently resides in Bethesda, MD, with his wife, Beeshyn. He has two daughters, Wynn, a lawyer, and I-Hua, a medical student.

Education and Outreach

Emilie Rank

A new feature, on GSFC's Earth Sciences (GES) DAAC Web site, called the "SeaWiFS Science Focus," has been implemented to provide information in a tutorial manner similar to the DAAC's "CZCS Classic Images" Web site. Notable phenomena related to ocean color will be explored using SeaWiFS data, along with explanations and accompanying graphics and images. (See http://daac.gsfc.nasa.gov/CAMPAIGN DOCS/OCDST/charleston bump.html.) Geared to address a community with various interests, this work exemplifies how to bring Earth science data to the general public in a very real and interesting way.

Toni Dufficy, National Park Service (NPS) Liaison to GSFC, and Carla Evans, GSFC Earth Sciences Directorate, Scientific and Educational Endeavors specialist, attended the National Association for Interpretation Workshop October 20-24, 1998, in Anchorage, Alaska. Their goal was to increase awareness about the NASA (GSFC in particular) educational and outreach resources. During the workshop, they contacted over 400 interpreters who promote science and math literacy. Interpreters are the people in private, local, State, and Federal parks and museums who prepare and present public programs. Carla and Tony have been requested to present an 8 hours training workshop on Remote Sensing for the 1999 National Interpreters Workshop.

Space-science resources are being used to create educational kits for the Rock Creek Park planetarium in Washington, DC.

Earth-science resources have been used by a Richmond National Battlefield ranger to support a local science fair.

The National Geographic Society has just published the new edition of *Satellite Atlas of the World* featuring images from several GSFC Earth science missions. The cover of this new edition features the image of the global biosphere produced from data collected by the SeaWiFS instrument. The atlas is available in bookstores, and the cover image can be viewed by linking to commercial online bookstores from the National Geographic Web site: http://www. nationalgeographic.com/index.html.

The American Physical Society (APS) has provided still images and video featuring high-resolution images of the Nimbus-7 TOMS observations of the development of the ozone hole. They will be incorporated into their traveling exhibit, called Noble Discoveries. It will open in March in Atlanta at the Centennial Meeting of the APS. The exhibit will travel to science and technology centers, museums, and educational sites around the country over the next 5 years. It is aimed at young people and the general public.

Dr. Elissa Levine (Code 923) and other scientists took part in a GLOBE Web Chat on February 25, 1999, with students and teachers across the world. The topic of the chat, "Careers," received a high number of participants with provocative questions. Transcripts of this and other GLOBE Web chats are available on the GLOBE Web page: www.globe.gov.

Dr. Levine also presented a talk on the GLOBE project at the USDA National Resources Conservation Service (NRCS) State Soil scientists meeting in Memphis, Tennessee. Dr. Levine solicited assistance from these scientists for guidance with the GLOBE student data for Earth science research. The talk met with a great deal of support and enthusiasm about the GLOBE project, incorporating soil science into the public school curriculum, and potential for research projects.

Dr. Paul Lowman, Code 921, held a 1-1/2 hour videoconference with students at Brunswick High School, Brunswick, Maine, at the request of the Educational Programs Office. Students asked questions about everything imaginable: What are the best areas for space photography (they're in the EarthCam project); possibility of transforming our understanding of Ganymede, the Moon, Mercury or Mars; Lowman's most exciting experience (flying a T-39 for 10 minutes); how he got into geology; can we deflect an Earth-crossing asteroid? Sponsoring teacher Diane Bowen said it was a huge hit.

Members of the Mesoscale Atmospheric Processes Branch (Code 912) participated in the Faculty Awards for Research (FAR) Participants Forum held at Goddard February 25-26, 1999. This program supports research by faculty at Historically Black Colleges and Universities (HBCUs). The Branch's participation is centered on Prof. Patrick Fitzpatrick of Jackson State University, who is engaged in hurricane and other mesoscale research. Bob Adler of Code 912 is the Technical Monitor on the JSU grant. Prof. Fitzpatrick gave a talk on his research at the forum and visited the Branch for additional discussions on hurricane studies, mesoscale modeling, and field-experiment data with Scott Braun, Ed Rodgers, and Marshall Shepherd. Possible areas for joint research and involvement of Jackson State students were discussed.

Dr. Dorothy Hall (Code 974) presented an invited talk on Alaska to the Luxmanor Elementary School (Rockville, MD) 3rd grade class on November 30, 1998, and another

invited talk on glaciers to the Tilden Middle School (Rockville, MD) Environmental Club on March 16, 1999.

On April 9, 1999, the president of the Crownpoint Institute of Technology, Mr. James Tutt, met with GSFC's Earth Sciences (GES) DAAC personnel. This meeting provided the opportunity for the GES DAAC to discuss collaborative efforts with three partnered Tribal Colleges of the Navajo Nation. This significant data applications effort involves determining the feasibility of providing Earth observing data to these colleges for educational and land-management purposes.

The GSFC Laboratory for Terrestrial Physics and the U.S. Geological Survey's Biological Resources Division created an educational Web site, "Adventures of Echo the Bat," for elementary and middle-school kids to help present remote-sensing science to children at a young age. A bat's migration was used as a way to bring together concepts of remote sensing science and biodiversity and as a way for the students to apply the concepts that they have learned. The Web site address is http://imagers.gsfc.nasa.gov.

AWARDS

Dr. Antonio Tony Busalacchi, Code 970, was chosen by President Clinton to receive the 1998 Presidential Rank of Meritorious Executive award.

Dr. Vincent V. Salomonson, Code 900, was chosen by President Clinton to receive the 1998 Presidential Rank of Distinguished Executive award.

Don Becker, a Code 930 staff scientist with the Center of Excellence in Space Data and Information Sciences (CESDIS), part of the University Space Research Association, is the recipient of the 1999 Excellence in Programming Award.

James A. Smith, Code 920, received the IEEE Geosciences and Remote Sensing Society Outstanding Service Award at the IGARSS '99 meeting this summer in Hamburg. Goddard now has two individuals who have received this award. Dr. Vincent V. Salomonson was the 1997 recipient.

Dr. Franco Einaudi, Code 910, has been elected a Fellow of the American Meteorological Society (AMS) for his outstanding contributions to atmospheric sciences. He was honored as a fellow on January 13, 1999, at the 79th American Meteorological Society Annual Meeting in Dallas.

Dr. Norden Huang, Code 970, received a NASA Space Act Award in the exceptional category for his invention of the Hilbert-Huang Transformation Method, a unique spectral analysis method for analyzing nonlinear and nonstationary data and images. The NASA Headquarters Inventions and Contributions Board recognized the new method of data analysis "as one of the most important discoveries in the field of applied mathematics in NASA history." (See page 9.)

Susan Reising, Code 903, received the 1999 Federal Executive Board (FEB) Excellence in Federal Career Program Bronze Award for Outstanding Professional–Administrative, Management, and Specialist. The award was presented to her at a luncheon and ceremony on May 7, 1999, at Martin's West in Baltimore.

Bill Campbell, Code 935, is the recipient of a 1999 American Society for Photogrammetry and Remote Sensing Presidential Citation for his contributions and support as Associate Editor of the Society's journal, *Photogrammetric Engineering and Remote Sensing*. The presentation took place at the ASPRS Annual Convention in Portland, Oregon on May 20, 1999.

Dr. Joanne Simpson has been elected an "Honorary Member" of the Royal Meteorological Society.

1998 GSFC Honor Awards on January 14, 1999:

Dr. William K. M. Lau, Code 913, The Outstanding Leadership Award
Dr. David Herring, Science Systems Applications, Inc., Code 913, Excellence in Outreach Award
Dr. Yoram Kaufman, Code 913, Outstanding Mentor Award
Dr. Franco Einaudi, Code 910, Diversity Enhancement Award
Dr. Walter Hoegy, Code 916, Diversity Enhancement Award
Dr. Antonio Busalacchi, Code 970, Excellence in Outreach Award
Gregory Shirah, Code 935, Excellence in Outreach Award
EGM96 Gravity Model Development Team, Code 926, Group Award

Recipients of Quarterly Honor Awards:

Minghan Leo Tsay, son of Dr. Si Chee Tsay (Code 913), is a winner this year of the NASA College Scholarship Fund.
Dr. Dennis Chesters, Code 912, Customer Excellence Award.
Joanne Woytek, Code 931, Customer Excellence Award.

(Continued From front page)

Message From the Director

models, regional effects/downscaling, and water and energy cycles; 2) global carbon-cycle research, including changes in the biology and biogeochemistry of ecosystems (terrestrial and oceans); 3) greater collaboration with academia, including use of NASA capabilities, through joint Center arrangements and the establishment of a GSFC Earth Science and Technology (GEST) Center (cooperative agreement); 4) more aggressive development of advanced technologies following paths identified by the "Earth Science Vision" effort, including ideas such as "constellation missions;" and 5) development and spin-off of applications of Earth science research working with other Government agencies, HQ/Code YO, and commercialization organizations, including Stennis Space Center. It was emphasized that these were broad, Directorate-wide thrusts indicating where the Directorate as a whole would try to proceed in the future, but specific thrusts that fall outside the efforts noted above are not necessarily to be diminished or precluded. All efforts, large or small, ultimately would have to survive the competitive, peer-reviewed processes defined by NASA Headquarters.

In its report (dated July 12, 1999) to the Directorate, the Visiting Committee was quite constructive and offered suggestions as to how the Directorate could improve progress and plans. In summary, the Committee report is divided into three sections discussing: 1) Areas of noteworthy strength; 2) three key issues having to do with: a) engineering support and Directorate competitiveness, b) human resources, and c) developing synergistic teams and alliances; and 3) seven additional issues of importance. Overall, the review went well and I feel that the Directorate is indebted to the Visiting Committee for taking time from their very busy schedules to offer their suggestions and guidance. As always, after having completed such a review, I find myself quite grateful and proud of the many accomplishments by Directorate personnel and the high quality of the work leading to a very considerable reputation throughout the Earth science community.

With the end of fiscal year 1999 approaching, there are lots of challenges and events to look forward to in the not too distant future. From the flight projects perspective, the successful launch of several missions (e.g., Terra) will be very important to Earth sciences in general, and to Goddard and this Directorate in particular. There are immense challenges looming on the budgetary front wherein we will have to wait and see how the FY2000 support for NASA Earth science turns out. In the face of all this, I urge everyone to continue to do their customary excellent work and, concomitantly, to make extra efforts to be sure that not only the scientific community is aware of what is being accomplished, but also the general public. In the latter instance, it seems that there are many people who still do not know and appreciate all the good things that happen at Goddard and in this Directorate. In order to sustain the support for Earth science, I urge everyone to do whatever they can to keep the public informed so that they can then provide knowledgeable opinions to the U. S. Congress and others of influence.

[Note: The full report of the Earth Sciences Directorate Visiting Committee can be found on the Web at http://esdcd.gsfc.nasa.gov/ESD/review.html]

Larry O'Hanlon Is First Earth Science Reporting Fellow

Larry becomes the first NASA-Discovery Online fellow and will divide his 3-month's fellowship time between Discovery's corporate office in Bethesda and Goddard, where he will have an office in our Earth and Space Computing Division's (Code 930) Science Visualization Studio. Larry will be a "correspondent in residence" with the job of gathering up as many of our science products as he can and turning them into "appealing, informative, and educational formats suitable for mass public consumption via popular news web sites." The results of Larry's work will appear on Discovery's Earth Alert!, on Discovery's Science Live!, and on the Science Channel. Larry's been doing science writing for 7 years and has won numerous writing awards. He has earned a graduate degree in Science Writing from the University of California, Santa Cruz.

Earth Sciences News

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